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Electrometallurgy in 1913

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By G. A. Roush

The advances in the various lines of electrometallurgy are so numerous, so diverse, and so widely scattered in the literature, that in the preparation of a review of this kind, all one can hope to do is to select some of the more striking discoveries in the more important fields to serve as illustrations of the general trend of the industry. What the breadth of these advances has amounted to, as measured from time to time, can probably be fully appreciated only when one considers the enormous development of electrometallurgy as it stands today, and measures up against it the comparatively short span of years through which this development has extended. By thus setting up the milestones, as it were, one secures a better idea of the general perspective into which this brief sketch of recent progress must fit.

Copper

So far as the current literature shows, there are no copper ores being treated at the present time in the electric furnace in this country. Trial smeltings of copper in a 1000-hp. furnace with an estimated production of 2000 tons per year have been reported from the Ilen Smelting Works at Trondhjem, Norway, but no detailed data concerning these experiments have been found.

An article in *Elec. Rev. West. Elec.*[1] describes electric copper smelting tried at Globe, Arizona. Test runs showed an extraction of 98% of the copper content of the ores. The furnace was of the vertical-shaft resistance type, 6 ft. in height, and lined with magnesia bricks. The opening of the furnace was 22 in. diameter at the top and 20 in. at the bottom, with a 5-in. Acheson graphite electrode swung at the top and a stationary electrode fixed at the bottom. Heating was started by an arc, and continued as resistance heating as soon as the charge was sufficiently melted. The power required was 3500 kw-h. per ton of charge.

Stephan[2] gives an account of experiments on the reduction of copper and nickel in furnaces similar to the Girod steel furnace. It was attempted to reduce a copper oxide ore high in silica and carrying some iron and cobalt, using solid carbon as a reducing agent, and limestone as a flux. A continuous run of several days resulted in a power consumption of 1000 to 1200 kw-h. per ton of ore. This figure is high on account of the high temperature required to keep the very viscous slag fused. With a more easily fluxed ore, the power consumption was as low as 500 kw-h. Charcoal, coke, and anthracite, to the extent of 25% of the copper in the charge, were all used successfully as reducing agent. The pig copper produced carried

[1] Volume 63, page 636.

[2] *Metall u. Erz*, Vol. 10, pp. 11-17, 84-86; *Met. Chem. Eng.*, Vol. 11, pp. 22-23.

65 to 95% Cu, 1 to 21% Fe, and 1 to 11% CO, depending on the temperature conditions in the furnace. The lower the temperature, the smaller was the amount of impurities reduced, but the larger the loss in unreduced copper.

Lyon and Keeney[3] report a series of experiments on the smelting of copper in the electric furnace. Experiments on sulphide ores, where the smelting consists simply in melting down the ore, volatilizing out sulphur, and separating the slag and matte, indicated that in a furnace of commercial size the power consumption would be about 480 kw-h. per ton of ore for a low-grade ore producing a matte carrying 1.22% Cu. There was some loss of silver by volatilization, but very little gold or copper. The authors conclude that the smelting can be done as efficiently in the electric furnace as in the reverberatory or blast-furnace, and the desired reactions can be carried out as satisfactorily.

This does not include patents granted on a number of different forms of electric furnace, and various electrometallurgical processes, concerning which nothing is known outside of the patent claims.

On the whole, the problem of the electric furnace reduction of copper seems now to be on about the same ground as the electric furnace reduction of iron was a few years ago. It is largely a question of the substitution of electric heating for carbon heating, which means that it is largely a question of the comparative cost, at a given locality, of electricity and coal or coke, and the relative efficiency with which they can be utilized. The electric furnace under these conditions is not the competitor of the combustion furnace, but a substitute for the combustion furnace under certain conditions.

Electrolytic Refining

Burns[4] describes experiments on the electrolytic refining of copper precipitate anodes. About 1400 tons of copper precipitate was melted down in the reverberatory furnace, about 25% of the charge being anode scrap, etc. The results showed that wire bar copper could be produced from these anodes at a current density of 17 to 18 amperes per square foot, while ingot grade copper is produced at a current density of 33 to 35 amperes per square foot.

Peterson[5] describes the leaching process of the Butte & Duluth Mining Co., Butte, Montana. These ores are oxidized varieties, carrying about 2% Cu, readily soluble in dilute sulphuric acid. Leaching with 10% acid for 24 hours dissolves the copper from the ore, and the acid solution is then electrolyzed, recovering the copper and regenerating the acid, which can then be used for further leaching, after the addition of sufficient acid to restore the original concentration, and make up for losses throughout the process. This amounts to about 3½ lb. of acid per pound of copper recovered. The power used is about 1 kw-h. per pound of copper. The copper produced analyzes about 99.96% pure.

Then there is the sulphatizing roasting of copper ores, followed by leaching and electro-deposition. Sulphide copper ores are roasted under conditions giving a maximum formation of sulphate. In this way 93 to 95% of the copper content of the ore can be made soluble in dilute sulphuric acid. The acid leach solution is then electrolyzed for the recovery of the copper and the regeneration of the acid, which can then be used for further leaching.

Zinc

Of all the different metals that are being treated by electro-metallurgical processes, probably none has been the subject of more discussion than zinc. Iron and steel take precedence over zinc only in the importance of the greater tonnage involved. Zinc secures this attention because of the proportionately small amount of progress that has been made in recent years along the lines of the present standard methods of treating zinc ores, and the possibility, not only of developing a process that can be run at a better efficiency than the present pyro-metallurgical methods, but also the possibility of securing a method of treating ores that cannot be treated at all by the present methods. And it is in this latter field that the electro-metallurgy of zinc promises the most satisfactory returns, at least for the immediate future. Numerous patents on furnaces and processes have been granted during the past year, but as little is known concerning most of these, beyond the claims stated in the patent, I will confine myself to the various publications of the past year giving the results of experimental work and information in regard to the general condition of the electro-metallurgical side of the zinc industry.

Uebbing[6] describes two methods of working a zinc-bearing burned pyrite. The first method was by a reducing smelting in an electric furnace, using CaO to assist in slagging the sulphur. Most of the zinc was volatilized from the charge, and the iron was obtained as pig iron. In order not to have too much sulphur in the pig iron, it would be necessary to reduce the sulphur in the raw material to less than one per cent. The second method consisted in reducing the sulphur by further roasting, briquetting the pulverized material with tar or pitch, and heating. A preliminary baking produced a part reduction, and subsequent heating in a vacuum furnace at 1000 to 1100° reduced all the iron and distilled out the zinc.

On account of the low cost of power, the Scandinavian countries have progressed further in the commercial application of electric zinc-smelting than have any of the other countries. There is one plant in Sweden, one in Norway, and it has been recently reported that a plant has been started in Finland, using 2500 hp.,

[3] *Bull.* No. 80, Amer. Inst. Min. Eng., pp. 2117-2149.

[4] *Bull.* No. 79, Amer. Inst. Min. Eng., pp. 1163-7; *Min. Eng. World*, Vol. 39, pp. 469-70.

[5] *Min. Eng. World*, Vol. 39, pp. 423-5.

[6] *Metall u. Erz.* Vol. 10, pp. 1 and 607-611.

which is to be later increased to 6000 hp. In the *Australian Mining Standard*[7] it is stated that the Sulphide Corporation has constructed at Cockle Creek, New South Wales, a 500-hp. electric furnace for the electric smelting of zinc, combined with the manufacture of sulphuric acid and superphosphate.

A recent report of the directors of the Hydraulic Power & Smelting Co., Ltd., gives the following information in regard to Scandinavian zinc smelting. The capacity of the works at Sundlokken (Sharpsborg), Norway, has been increased from 8000 to 10,000 tons per year, and contracts for the sale of the entire coming year's production have been made under terms giving a satisfactory profit. The erection and equipment of a new plant at Trollhättan, Sweden, is being pushed as rapidly as possible, and 13 furnaces of 1000 hp. and 8 of 500 hp. have been installed. Five more 1000-hp. furnaces will be built.

The problem of electric zinc-smelting is being studied in Canada under the direction of Stansfield and Ingalls, under a grant from the Canadian Government, but no recent publications have been made by them. The leading investigators in this country are Johnson and Peterson, both of whose processes are described in considerable detail in papers presented at the Denver meeting of the American Electrochemical Society, September 1913.[8]

Zinc Smelting Near

While there have been no radical improvements in the various processes for the electric smelting of zinc during the past year, the gradual advance of the experimental and semi-commercial processes that are being tried out seems to lead to the conclusion that for complex ores, where the recovery of the zinc must be accompanied by the simultaneous recovery of copper, lead, silver, and gold, electric smelting processes show decided possibilities. After considering the various sides of the question, Ingalls comes to the conclusion that if the zinc can be smelted with an expenditure of not more than 1200 kw-h. per ton of ore, the electric smelting processes will become a possibility worth considering. Johnson, in the article cited above, publishes values of kilowatt-hours per ton ranging from 1100 to 1700, and expects to secure still better results with further development of his process, and, with larger size furnaces, Peterson figures on a basis of 1400 kw-h. per ton of ore.

All things considered, the electric smelting of zinc seems to be a commercial possibility of the near future. The fact that the zinc can be reduced, and that the other metals of the ore can be satisfactorily recovered, have been already shown. The principal things remaining to be done are, first, to control the condensation of the zinc vapor so that a satisfactory percentage of it is condensed as metallic zinc, instead of blue powder, and second, to control the furnace operation so that the cost of replacing electrodes does not exceed the present cost for retorts and condensers.

Iron and Steel

The electric reduction of iron is certainly no longer in the experimental stage. It is meeting the requirements in the localities where it has been introduced, and for some uses the electric furnace produces a more suitable metal than the blast-furnace. For example, electric-furnace pig iron can be made much lower in impurities than ordinary blast-furnace pig iron, which makes it much easier to convert into steel in the open-hearth furnace.

The electric iron-smelting furnace at Trollhättan has, according to a writer in *Engineering*,[9] been modified to use round electrodes 600 mm. in diameter, and an apparatus has also been added to purify the gas by washing. The furnace used 1749 kw-h. to produce 1000 kg. of iron, an efficiency of 74.39%. The consumption of charcoal is only 35 to 45% of that required in the blast-furnace. From results secured at Trollhättan it appears that the electric furnace is subject to greater variations than a well run blast-furnace and that the sulphur content of the iron is higher.

As a result of the successful operation of the Trollhättan furnace, three other furnaces have been built in Sweden, the four using 12,000 hp.; in Norway there is one 3500-hp. furnace in operation, and three 3000-hp. furnaces are under construction; in Switzerland a 2500-hp. furnace is being built; these, with the two California furnaces, one of 2000 hp. and the other of 3000 hp., make a total of 32,000 hp. for use in the electric reduction of iron.

Lyon[10] compares Scandinavian practice with the electric iron furnace with California practice. The main differences are that in California no attempt is made to secure any reduction in the stack of the furnace, there is no circulation of the furnace gases, and the limestone used is calcined outside of the furnace. Further details on the operation of the California furnaces are given by Crawford[11]. The minimum power consumption under present working conditions is given as 2200 kw-h. per ton of pig iron. The efficiency is not quite so high as the Swedish shaft-furnaces of the same power rating, but the extension of the length of the furnace is expected to remedy this, since the end electrodes work at a lower efficiency than the electrodes in the centre of the furnace, due to the increased radiating surface.

The size of the units in use is constantly increasing. Most of the Scandinavian furnaces are rated at 3000 hp., but it is reported that the A. B. Elektrometall has completed the design of a 7500-hp. furnace. The California experiments have led to the development of a furnace rectangular in shape, with the electrodes in a straight line, and it is thought that it will be possible to increase the length of this furnace indefin-

[7] May 22, 1913, abst. *Met. Chem. Eng.*, Vol. 11, p. 463.

[8] *Trans.* Amer. Electrochem. Soc., Vol. 24.

[9] Vol. 94, pp. 395-7 and 630-5.

[10] *Met. Chem. Eng.*, Vol. 11, pp. 15-19.

[11] *Mining and Scientific Press*, June 28; *Met. Chem. Eng.*, Vol. 11, pp. 383-8.

itely, as has been done with the modern rectangular copper blast-furnace.

A good summary of the present status of the electric furnace in smelting of iron ores is given by Lyon and Keeney in their paper,[12] 'Possible Applications of the Electric Furnace to Western Metallurgy,' presented at the Denver meeting of the American Electrochemical Society in September 1913.[13]

The principal advances in the electro-metallurgy of steel are along the line of increased size of furnaces, and better control of the furnace operation, giving greater capacity and more thorough purification of the charge. An induction furnace of 25 tons capacity has recently been constructed in Germany. The electric furnace is also proposed as a holder for melted steel, giving the steel time to clear itself of gas and slag before it is cast.

The number of electric steel furnaces now in operation are as follows: Europe, 112; United States, 19. The production of electric-furnace steel is rapidly increasing in Europe, the 1912 production being about 11,000 tons more than the 1911 production. In the United States, however, the production has decreased about the same amount in the same time.

The Société le Fer[14] effects the removal of the hydrogen in the production of electrolytic iron by adding to the bath Fe_2O_3, which is reduced to FeO. Iron of high quality is obtained with a current efficiency of 95 to 98%, even with current densities as high as 1000 amp. per square metre.

Ferro-Alloys

The growth of the ferro-alloy industry in the United States has been much slower than in Europe, this country having only two plants using electric-furnace processes, compared with 25 in Europe. This makes the production of the ferro-alloys, particularly of manganese, silicon, and tungsten, of interest in this country, since the production is not sufficient to meet the demand, and large quantities are imported annually, while the growing importance of high-grade and alloy steels is making these alloys of continually increasing importance. The production of ferrochrome, ferrotitanium, and ferrovanadium is sufficient to meet the domestic demand. The principal reason for the more rapid growth in Europe is the fact that power can be obtained cheaper than in this country. Ores of chromium, tungsten, molybdenum, and vanadium are found in the western United States in sufficient quantities to make further development of ferro-alloy manufacture well worth while. Keeney[15] gives the results of a series of experiments in the manufacture of the various ferro-alloys in the electric furnace. Flöge[16] describes the use of an electric furnace for melting the ferro-manganese used to de-oxidize steel, resulting in a saving of 35% of the amount required when it is added in the solid form, besides giving uniform quality of metal and saving considerable time. Bingham[17] patents the production of ferrosilicon using as a raw material scrap silica bricks from the lining of open-hearth furnaces, that are partly saturated with iron.

Gold and Minor Metals

The electric furnace has not yet been applied to the working of gold or silver ores, although there are conditions under which this might be advantageous. There has recently been installed at Lluvia del Oro, Chihuahua, Mexico, a furnace for the electric smelting of the zinc precipitate from the cyanide plant and smelting ore concentrates. The bullion is shipped and the slag is re-smelted or concentrated.

The electric smelting of straight lead ores has not been attempted, largely because of the ease with which these ores can be handled in combustion furnaces.

Working in a small furnace, Stephan[18] reduced from an ore containing 8.33% NiO 350 kg. of ferro-nickel, carrying 4.33% Si. The power consumption was about 2000 kw-h. per ton of ore, which could probably be reduced to about 1200 kw-h. in working.

The increased use of platinum in jewelry makes it desirable to have a small furnace capable of melting over scrap to recast into ingots. In *Brass World*[19] a small 'Hellberger' furnace is described. This is a small electric furnace with a removable crucible, taking 110 or 220 volts, a special transformer cutting this down to the desired voltage. One kilogram of platinum requires 10 kw-h. for melting.

Particulars concerning some experiments made by the Gröndal-Kjellin Co., of London, in smelting tin ores in Cornwall, are contained in the *Revue Industrielle*. Pure ores yielded metal of 98% purity, and Bolivian ores containing about 50% of tin and 15% of iron gave metal of 92 to 97% purity. The latter could be further refined to a purity of 99.75% by blowing air through the molten mass. The energy consumed was 1700 kw-h. per ton, but this may be reduced to 1400 kw.h. with an efficiency of 55% by using two furnaces, one for the production of high-grade metal and the other being used for the treatment of rich slags.[20]

Michaud and Delasson[21] patent the electrolytic refining of tin in a $SnCl_2$ solution carrying some $MgCl_2$ and H_3BO_3. The tin-bearing material is placed in a flat porous basket that serves as anode, and the cathode is a copper plate, from which the deposited tin is removed by scrapers. In order to keep the electrolyte saturated with tin, it is circulated through a container filled with tin scrap. The yield is 2.22 gm. of tin per ampere-hour.

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[12] *Mining and Scientific Press*, Nov. 1.

[13] See also *Mining and Scientific Press*, Dec. 20.

[14] Fr. Pat. 446,614, Oct. 6, 1911.

[15] *Trans.* Amer. Electrochem. Soc., Vol. 24.

[16] *Chem. Zeit.*, Vol. 36, p. 307.

[17] Brit. Pat. 22,755, Oct. 16, 1911.

[18] *Metall u. Erz.* Vol 10, pp. 11-77, 84-86; *Met. Chem. Eng.* Vol. 11, pp. 22-23.

[19] Vol. 8, p. 273.

[20] *Met. Chem. Eng.*, Vol. 11, p. 653.

[21] Fr. Pat. 435,936, and addition 16,388, Aug. 24, 1912.